Draft
Site Visit Report
Coalbed Methane Operations
Gillette, WY

Prepared for:

U.S. Environmental Protection Agency
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2.0 ATTENDEES

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3.0 OBJECTIVE

EPA is in the process of gathering data to develop a "Best Professional Judgment" determination of effluent limitations that represent Best Available Technology Economically Achievable (BAT) for coalbed methane (CBM) activities in Region 8 (i.e., Wyoming, Montana, Colorado, Utah, North Dakota, South Dakota). EPA and contractor personnel conducted site visits to coalbed methane operations in and around Gillette, Wyoming on August 6 and 7, 2001 as part of this data-gathering effort. The purpose of the visit was to gather information on coalbed methane operations in the Powder River Basin and specifically on techniques for managing the produced water. The coalbed methane operators selected these sites for visiting.

4.0 COALBED METHANE OPERATIONS

During the two-day site visit, 13 separate locations were visited. Each of these locations is described below.

4.1 Scooner Road

Barrett Resources Corporation is conducting a pilot CBM operation at this location that started in March 2001. The pilot project is to test the effectiveness of using atomizers to disperse the produced water and increase vegetative growth. At this location, Barrett Resources operates 15 CBM wells that are drilled to a depth of approximately 2,000 feet into the Big George coal formation. This location represents the deepest part of the Powder River Basin. The wells are spaced at one well per 80 acres. These wells currently produce approximately 50 to 60 gallons per minute (gpm) of water per well. The water is pumped up from the well using a progressive cavity pump. Figure 1 shows a picture of one of the wells with a progressive cavity pump. The produced water is piped to a large reservoir and storage tanks. Figures 2 and 3 show pictures of the produced water reservoir and storage tanks. The overflow of the tanks is piped to one of eight atomizers that have a fixed point sprinkler head. The atomizers can accommodate up to 60 gpm of water. Figure 4 shows a picture of one of the atomizers.

Figure 1: Progressive Cavity Pump at Scooner Road

Figure 2: Storage Tanks at Scooner Road

Figure 3: Reservoir at Scooner Road

Figure 4: Atomizer at Scooner Road

4.2 <u>Kuhn Ranch</u>

Pennaco Energy is operating CBM wells at this location. The wells are open hole cavity wells with a submersible pump. Frost boxes are installed over the well head to protect them from the elements. At this location, there was also a telemetry box for the well. Figure 5 shows a picture of the well head inside the frost box and Figure 6 shows a close-up picture of the well head.

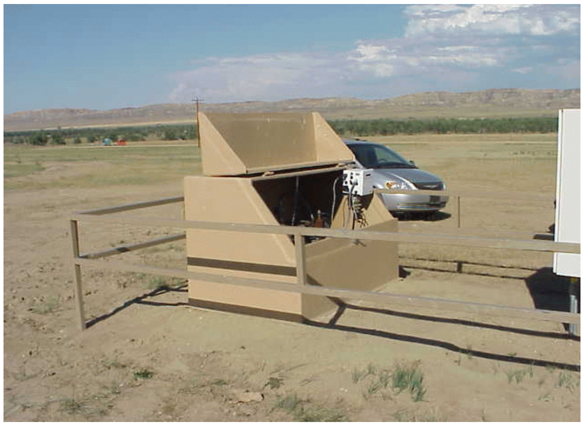

Figure 5: Well Head and Frost Box at Kuhn Ranch

Figure 6: Well Head at Kuhn Ranch

4.3 Tietjen Ranch

Pennaco Energy is operating CBM wells at this location. The produced water is managed in a number of different ways. Some the water is piped to a tire tank and used for livestock watering. Figure 7 shows a picture of the tire tank. Some produced water is piped to storage tanks and used for water enhancement work on the CBM wells. Enhancement work includes flushing the wells to remove coal fines that may be pumped up with water. Figure 8 shows a picture of the storage tanks. The remainder of the produced water from this location is piped into an evaporation pond. The water is discharged out of a perforated pipe and over limestone rocks (i.e., rip rap) to precipitate out the dissolved iron before the water reaches the pond. The precipitated iron causes red staining. By inducing the precipitation over the rocks, the staining can be limited to the rocks which can be removed and permanent staining of the ground is eliminated. Figure 9 shows a picture of the rip rap and evaporation pond.

Figure 7: Tire Tank at Tietjen Ranch

Figure 8: Storage Tanks at Tietjen Ranch

Figure 9: Rip Rap and Evaporation Pond at Tietjen Ranch

4.4 Wild Horse Creek

Wild Horse Creek is a Class 4 tributary to the Powder River located near Arveda, Wyoming. CMS Energy discharges approximately 1,344,000 gallons per day (gpd) into Wild Horse Creek from 290 CBM wells. There are also approximately 400 additional CBM wells being discharged to this creek from other operators. Due to evaporation and infiltration of the produced water into the shallow aquifers, the water flow in Wild Horse Creek is relatively slow. Figure 10 show a picture of Wild Horse Creek, about a quarter of a mile from its discharge into the Powder River.

Figure 10: Wild Horse Creek

4.5 CMS Water Reservoir

CMS Energy operates a number of CBM wells within the drainage to Wild Horse Creek. Figure 11 shows a picture of a CBM produced water reservoir. The water from the reservoir drains out into an empheral unnamed tributary of Wild Horse Creek. This tributary, near the discharge point has been lined with rocks to minimize erosion. Figure 12 shows a picture of the drainage onto rocks for erosion control and Figure 13 shows a picture of the unnamed tributary.

Figure 11: CMS Water Reservoir

Figure 12: CMS Water Reservoir Discharge

Figure 13: Unnamed Tributary at CMS Water Reservoir

4.6 <u>Failed CMS Injection Well</u>

Lee Sigman of CMS described a situation in which a reinjection project failed. The actual site of the failed injection well was not visited. At a location within the Wild Horse Creek drainage, near Arveda, Wyoming, CMS was developing a CBM field. One landowner with surface rights refused to allow water reservoirs to be built on his land and for produced water to be discharged to the creek on his property. The landowner is concerned that detrimental impacts to his land may occur. He currently flood irrigates his hayfields by damming the creek during rain events and diverting the water to the hayfields. Due to limited water discharge options, CMS tried to reinject the produced water from eight CBM wells that were producing approximately 162,000 gpd. CMS drilled the injection wells to a depth of 1,350 feet and reached 120 pounds of pressure. After six months, however, CMS was only able to reinject approximately 69,300 gpd per well due to limitations in the injection formation. This left CMS with 92,400 gpd per well of excess produced water that could not be reinjected. Since it was not economical for CMS to reinject the water and other surface water discharge options were limited, the area is now "shut in" and CMS has stopped production. In total, CMS believes they spent over $6 million to develop the field and try to manage the produced water.

4.7 <u>Felix Pilot Wetland</u>

Pennaco Energy is evaluating the potential to remove iron and barium in Carex (sedge)-dominated wetlands that are common in ephemeral drainages in northeastern Wyoming. The Felix pilot study is being conducted in an off-channel constructed wetland. The wetland treatment design consists of passive (abiotic) oxidation of ferrous iron to ferric which is conducted as water flows out of the pipe in the tire tank, followed by filtration through dense stands of native sedge, and then filtration through a sand bed. Finally, the water is discharge to the receiving stream. Figure 14 shows a picture of the tire tank and wetland area and Figure 15 shows a picture of the wetland area. Figure 16 shows a picture of the water flowing through the down gradient end of the wetland towards the sand bed filter and Figure 17 shows a picture of the sand bed filter. Figure 18 shows a picture of the discharge point to the receiving stream.

The native sedge (i.e., Carex utriculata (rostrata), C. aquatilis, C. nebraskensis) was planted in June, 2000 with one-foot spacing between plants. The wetland is designed to accept a flow of 30 to 40 gpm and the hydraulic residence time is estimated at one day. Preliminary findings indicate that iron removal is excellent but that barium removal is less efficient. Since the barium in the produced water is in an ionic carbonate form, a longer residence time may be required to allow the barium to recombine with sulfate and precipitate. Constructed wetlands are not expected to reduce the sodium adsorption ratio (SAR) of the produced water due to the short-residence time. Ancillary wildlife benefits appear excellent based on the enhancement of the wetland-riparian habitat.

Figure 14: Tire Tank and Felix Pilot Wetland

Figure 15: Felix Pilot Wetland

Figure 16: Water Flowing Through Felix Pilot Wetland

Figure 17: Sand Bed Filter at Felix Pilot Wetland

Figure 18: Felix Pilot Wetland Discharge Point

4.8 Jim Wolfe Ranch

Joe Olson of Pennaco Energy presented an overview of this location. At this location, Pennaco Energy built an aquifer storage and retrieval facility that was never put into operation. The facility cost approximately $450,000. Figure 19 shows a picture of the treatment facility. The facility is designed to collect produced water from 60 CBM wells into a water storage tank. Figure 20 shows a picture of the water tank. As the water enters the tank it hits a splash pan to facilitate separation of water, sediments, and methane gas. The water would then enter the treatment facility and flow through an ultraviolet light chamber with 32 bulbs arranged in a circular pattern. Figure 21 shows a picture of the ultraviolet light chamber. The system, however, was designed to handle a flow of approximately 1,000 gpm and the highest actual flow from the 60 wells was 380 gpm. The reduced flow resulted in biofouling of the bulbs and, therefore, light never reached the water. Pennaco Energy also found high sulfate concentrations in the produced water which prevented the water from being reinjected into the planned aquifer.

To manage the produced water from the 60 wells, Pennaco is collecting the water in the storage tank, metering the water, adding chlorine to disinfect the water, and piping the water to four injection wells in the area. Currently only two injection wells are being used. These injection wells are reclaimed oil and gas wells that were abandoned. Gravity flow is used to move water into the injection wells, which reduces cost. The water flow is now down to a third of the initial production flow.

Pennaco Energy has found that an average injection well may be able to accommodate a long-term injection rate of 120 to 150 gpm. Due to the problems associated with the Fort Union formation, however, many injection wells are unusable due to the presence of sands and limited area of extent. Well filters may need to be changed daily if particulates are a problem. The wells often increase the pressure in the formation too quickly and do not last. An ideal well would be drilled under screen or slot on the entire section. The cost of this type of well construction is approximately $200,000 to $250,000 per well and often too expensive for the amount of gas produced. Due to the possibility of injection wells failing, operators must always have another water management option available such as discharge to a receiving stream or discharge to an evaporation pond.

Figure 19: Treatment Facility at Jim Wolfe Ranch

Figure 20: Water Tank at Jim Wolfe Ranch

Figure 21: Ultraviolet Light Chamber at Jim Wolfe Ranch

4.9 Steinhopfel Facility

Pennaco Energy is operating a reinjection facility at this location because the landowner will not allow surface discharge on his property and reinjection was economically viable. This facility has been operating for approximately 1.5 years and has reinjected over 140 million gallons of water. Figure 22 shows a picture of the facility. Produced water from approximately 20 CBM wells is collected into a tank where it hits a splash pan to facilitate separation of water, sediments, and methane gas. The water is then metered and chlorine is added to disinfect the water. The water is then piped to a series of four injection wells. Only two injection wells are currently being used. The initial flow of the produced water was 280 gpm. The current flow is about 100 gpm. This facility cost approximately $120,000 to design and operate. Only one well has required rehabilitation to date. It is economically viable because the injection wells are downgradient from the facility and gravity feeds the water down into the injection wells which were abandoned oil and gas wells. This is possible because the aquifer is approximately 40 percent depleted . Pennaco Energy estimated that it would cost approximately $50,000 to install pumps to inject the water if the injection wells were not located downgradient of the facility and the receiving aquifer was not depleted.

Pennaco Energy tried to develop another reinjection project along Dead Horse Creek using an abandoned well that was originally cased to 8,000 feet. The well was plugged back to inject into the Fox Hill formation. After extensive maintenance to the well and over $200,000, the formation would only accept a flow of approximately 22 gpm. Hydraulic fracturing could have been used to increase water acceptance into the formation, however, Pennaco Energy determined it would be too expensive. Although reinjection into deeper aquifers is technically viable, Pennaco Energy believes it is not economically viable and due to the relative high quality of the produced water it is better to reinject the water into shallower aquifers so that it can be used. According to Pennaco Energy, many ranchers are able to double stock, move cattle to other areas for feed, and improve weight gain due to the beneficial reuse of produced water for livestock watering.

Figure 22: Steinhopfel Facility

4.10 Caballo Creek

Caballo Creek is an official Wyoming geologic monitoring station. Figure 23 shows a picture of Caballo Creek at the monitoring station. Several hundred CBM wells have been discharging above the creek for over 12 years. The current discharge rate to this area averages approximately 3 to 4 gpm/well. A "v-notch" in the creek at this location is used to estimate the flow rate. Water monitoring data from this area indicate a decrease in total dissolved solids (TDS) and SAR for the last 10 years. CBM operators believe adding produced water to the drainage area has helped reduce TDS and SAR concentrations. Caballo Creek flows into the Belle Fourche River and into South Dakota. There are several small reservoirs approximately six miles downstream from this location that are used for irrigation.

Figure 23: Caballo Creek

4.11 21-Mile View

This location provides a view of the divide between the Caballo Creek drainage and the Dead Horse Creek drainage. Figure 24 shows a picture looking West of Gillette, Wyoming.

Figure 24: 21-Mile View

4.12 Mankin Ranch

Phillips Petroleum is operating CBM wells at this location. Six newly installed CBM wells are discharging to the 21 Mile Butte Discharge point under NPDES Permit WY0038822. The produced water is piped to the tire tank and overflow is piped to the outfall location on Caballo Creek. Rocks around the tire tank were most likely installed to minimize the formation of mud as livestock drink from the tire tank. Figure 25 shows a picture of the tire tank. At the discharge point to Caballo Creek, the water flows out of a pipe onto limestone rocks to precipitate the dissolved iron. The rocks at the discharge point are also used to control/minimize erosion. Figure 26 shows a picture of the permitted outfall. Current flow from the discharge point is estimated at 15 to 20 gpm. Figure 27 shows a picture of Caballo Creek at the discharge point.

Figure 25: Tire Tank at Mankin Ranch

Figure 26: Permitted Outfall at Mankin Ranch

Figure 27: Caballo Creek at Mankin Ranch

4.13 Saunders Drilling Site

The final stop on the site visit tour was to a CBM drilling site operated by Barrett Resources Corporation. All CBM wells in this area are drilled to the top of the coal seam using water and then drilled through the coal seam and underreamed with air. The depth to the Wyodak coal seam at this site is 1,163 feet and the depth to the bottom of the coal is 1,220 feet. Once the hole is completed the area is cleaned using a combination of air and soap that is discharged through a pipe into a temporary pit. This pit which contains some water, coal, and soap is backfilled and revegetated. Figure 28 shows a picture of the truck-mounted drilling rig and the temporary pit.

Figure 28: Truck-Mounted Drilling Rig at Saunders Drilling Site